SC DHEC South Carolina Department of Health and Environmental Control

D H E C

PROMOTE PROTECT PROSPER

Ocean and Coastal Resource Management

South Carolina DHEC Storm Water Management BMP Handbook

August 2005

Appendices

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AMD	Acrylamide Polymer
BFM	Bonded Fiber Matrix
BMP(s)	Best Management Practice(s)
CFS	Cubic Feet Per Second
CMP	Corrugated Metal Pipe
DHEC	South Carolina Department of Health and Environmental Control
ECB	Erosion Control Blanket
EPA	United Stated Environmental Protection Agency
EPSC	Erosion Prevention and Sedimentation Control
FDA	United States Food and Drug Administration
FGM	Flexible Growth Matrix
HDPE	High Density Polyethylene
MS4	Municipal Separate Storm Sewer System
MSDS	Material Safety Data Sheets
NPDES	National Pollutant Discharge Elimination System
PAM	Polyacrylamide or Polymer
RCP	Reinforced Concrete Pipe
SCS	Soil Conservation Service
SWPPP	Storm Water Pollution Prevention Program
TRM	Turf Reinforcement Mat
VFS	Vegetated Filter Strip

Erosion Prevention and Sediment BMP Basic Design Procedures

Control of sedimentation from construction sites is accomplished through the utilization of a variety of erosion and sediment control Best Management Practices (BMPs). The complexity of the erosion prevention and sediment control (EPSC) plan varies depending on the individual site conditions. The goal of implementing the erosion control plan is to limit the quantity of sediment being eroded from, and leaving a construction site. This is partially accomplished through the implementation of sediment control BMPs. However, these sediment trapping controls typically only remove a small portion of the clay particles eroded from the site. The best protection is provided by a combination of practices including temporary and permanent stabilization, flow diversions, and streambank protection, all which minimize the amount of soil that is eroded from the site.

Plan land development to control and limit erosion and sediment discharge from construction sites using, but not limited to, the BMPs listed in this Manual. The goal of these erosion and sediment control BMPs is to:

- Minimize the extent and duration of disturbed soil exposure.
- Protect off-site and downstream locations, drainage systems and natural waterways from the impacts of erosion and sedimentation.
- Limit the exit velocities of the flow leaving the site to non-erosive or pre-development conditions.
- Design and implement an ongoing inspection and maintenance plan.

SCDHEC regulations require that when runoff drains to a single outlet from land disturbing activities which disturb ten (10) acres or more then a sediment basin must be designed to meet a removal efficiency of 80 percent for suspended solids or 0.5 mL/L peak settleable concentration, which ever is less. The design storm event associated with this level of control is the **10-year 24-hour SCS Type II, or Type III (coastal zone) storm event**. Computer software packages and the Design Aids contained in this handbook may used to calculate trapping efficiencies and peak settleable concentrations.

Land disturbance activities that are greater than five (5) acres require the development of EPSC plans to achieve an 80 percent design removal efficiency goal. Simply applied, when a site is completely denuded of vegetation, structural and nonstructural EPSC measures are designed to trap 80 percent of the total suspended solids (TSS) generated on the site.

Use SCS (Soil conservation Service) procedures to determine runoff amounts. It is important to note that when a BMP is designed for the 10-year 24-hour storm event, the BMP will have a greater trapping efficiency for more frequent events such as the 2-year 24-hour storm event.

EPSC plans delineate the following elements:

- All sensitive features.
- Sources of sediment that may potentially leave the site.

- The location and depth of all structural and nonstructural BMPs necessary to achieve the 80 percent design removal efficiency goal to protect receiving water bodies, off-site areas and all sensitive features.

- Installation and maintenance of required BMPs.

- The sequencing of construction activities to be utilized on the project.

Utilize the following nonstructural site management practices on the design plans where applicable:

- Minimize site disturbance to preserve and maintain existing vegetative cover.

- Limit the number of temporary access points to the site for land disturbing activities.

- Phase and sequence construction activities to minimize the extent and duration of disturbed soil exposure.

- Locate temporary and permanent soil disposal areas, haul roads and construction staging areas to minimize erosion, sediment transport and disturbance to existing vegetation.

Detailed EPSC plans comply with the following specific standards and review criteria:

- Sediment Tracking Control. Locate and utilize stabilized construction entrances at all points of ingress and egress on the construction site to prevent the transfer of sediment onto public roads and right-of-ways by motor vehicles and runoff.

- Crossings. Minimize the crossing of waterways during construction. Crossings must be approved by the U.S. Army Corps of Engineers and SCDHEC. Avoid encroachment into stream buffers, riparian areas, and wetlands when possible.

- Topsoil. Stockpile and preserve topsoil from erosion or dispersal both during and after site grading operations when applicable.

- Temporary Stabilization Measures. Temporary stabilization is required within 14 days after construction activity is complete **unless construction activity is going to resume within 21 days**.

- Final Stabilization. Prevent soil from eroding after the construction is complete. Final Stabilization of the site is required within 14 calendar days of construction completion.

- Temporary Structural Controls. Design to accomplish maximum stabilization, prevent erosion and control sedimentation. Design temporary structural controls to control the peak runoff resulting from the design storm event. Install, maintain, and remove temporary controls according to the specifications set forth in this BMP Manual.

- Permanent Structural Controls. Design all permanent controls including channels, storm sewer inlets, detention basins, and water quality structures according to State Regulations and to the standards set forth in the BMP Manual.

Erosion Prevention Measures

Use erosion prevention measures during and after construction site preparation in order to safely convey clean water to storm drains or adequate watercourses. One or more measures should be utilized as appropriate during the project's construction phase. Such measures may include but are not limited to: phasing and construction sequencing, surface roughening, temporary seeding, mulching, erosion control blankets, and reinforcement matting. Each of these measures is discussed in the Sections below.

In addition to site-specific erosion control measures, the grading plan includes the following general measures as a minimum:

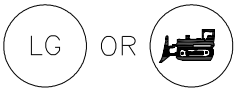
- Vegetated finished cut and fill slopes should not be steeper than 3H:1V, unless an erosion control blanket or turf reinforcement mat is used.
- Do not place cuts or fills close to property, endangering adjoining property without adequately protecting such properties against erosion, sedimentation, slippage, settlement, subsidence, or other damages.
- Provide subsurface drainage in areas having a high water table to intercept seepage that affects slope stability, bearing strength, and undesirable wetness.
- Do not place fill material where it can slide or wash onto another property.
- Do not place fill adjacent to channel banks where it can create bank failure, reduce the capacity of the stream, or result in downstream sediment deposition.
- Include all borrow and disposal areas as part of the grading plan.
- Provide adequate channels and floodways to safely convey increased runoff from the developed area to an adequate outlet without causing significant channel degradation, or increased off-site flooding.
- Grade the site to direct flows to appropriate controls.

The following Erosion Prevention Measures are discussed in this handbook:

- Surface Roughening
- Temporary Seeding
- Mulching
- Erosion Control Blankets (ECBs)
- Turf Reinforcement Mats (TRMs)
- Flexible Growth Matrix (FGM)
- Bonded Fiber Matrix (BFM)
- Permanent Seeding
- Sodding
- Riprap
- Outlet Protection
- Dust Control
- Polyacrylamide (PAM)

Surface Roughening

Plan Symbol



Description

Surface roughening is the creation of horizontal grooves, depressions, or steps that run parallel to the contour of the land. The following surface roughening measures are approved for use:

- Tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints parallel to the slope contour).
- Stair-step grading.
- Grooving (using disks, spring harrows, or teeth on the bucket of a front-end loader).

Tracking

Description

Tracking is defined as driving tracked machinery up and down slopes, leaving the cleat imprints parallel to the slope contour.

When and Where to Use It

To slow erosion, perform tracking as soon as possible after the vegetation has been removed from the slope. Use tracking with temporary seeding and temporary mulching to stabilize an area.Perform tracking immediately after grading activities have ceased (temporarily or permanently) in an area.

Installation

Avoid excessive compacting of the soil surface when tracking since ~~because~~ soil compaction inhibits vegetation growth and causes higher runoff rates. As few passes as possible should be made with the machinery in order to minimize compaction

Seed and mulch surface roughened areas by the means of tracking within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Stair-Step Grading

Description

Stair-Step Grading is defined as cutting stair-steps into slopes with each step having a maximum horizontal distance of 4-feet and a maximum vertical distance of 4-feet.

When and Where to Use It

To slow erosion, perform stair step grading within 7 days after the removal of vegetation from the slope. Stair step grading is applicable on cut slopes with a gradient steeper than 3H:1V but less than 2H:1V. Stair-step grading is applicable on any material soft enough to be moved with a bulldozer. Stair-step grading works well with soils containing large amounts of small rock. Prepare stairs wide enough to work with standard earth moving equipment. Stair-step grading is used with seeding to stabilize an area.

Installation

The ratio of vertical cut distance to horizontal distance is steeper than 1V:1H and the horizontal portion of the "step" slopes towards the vertical wall.

Seed and stabilize areas graded in this manner within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Grooving

Description

Slope Grooving is defined as using machinery to create a series of ridges and depressions that run perpendicular to the slope on the contour.

When and Where to Use It

To slow erosion, perform slope grooving within 7 days after the removal of vegetation from the slope.

Groove cut and fill slopes with a gradient steeper than 3H:1V but less than 2H:1V. Grooving is done by any implement that is safely operated on the slope.

Slope Grooving is used with seeding and planting to stabilize an area.

Installation

Install slope grooving with any appropriate implement that is safely operated on the slope not causing undue compaction. Suggested implements include discs, chisel plows, and the teeth on a front-end loader bucket. Install grooves a minimum of three inches deep and no further than 15 inches apart.

Seed and stabilize areas that are graded in this manner within 14 days.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, re-grade and re-seed immediately.

Surface Roughening (Tracking)

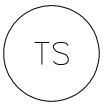
Surface Roughening (Tracking)

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Rills appear.	Re-grade and re-seed area immediately.

Temporary Seeding

Plan Symbol



Description

The purpose of temporary seeding is to reduce erosion and sedimentation by stabilizing disturbed areas that would otherwise lay bare for long periods of time before they are worked or stabilized. Temporary seeding is also used where permanent vegetation growth is not necessary or appropriate.

When and Where to Use It

Temporary seeding is used on exposed soil surfaces such as denuded areas, soil stockpiles, dikes, dams, banks of sediment basins, banks of sediment traps, and temporary road banks. Temporary seeding prevents and limits costly maintenance operations on other sediment control structures. Sediment clean-out requirements for sediment basins, sediment, traps, and silt fence is reduced if the drainage area is seeded when grading and construction operation are not taking place.

Temporary stabilization is required within 14 days after construction activity is complete **unless construction activity is going to resume within 21 days**. Cover seeded areas with an appropriate mulch to provide protection from the weather. When the temporary vegetation does not grow quickly or thick enough to prevent erosion, re-seed as soon as possible. Keep seeded areas adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Seed Selection

Seed selection is based on geographical location, soil type and the season of the year in which the planting is to be done. Use the tables in Appendix C as a guide for conventional tillage methods (plowing, seedbed preparation, hydroseeding, etc). If a fast growing crop to nurse the permanent specie or species is required, then use the mix rate. Failure to carefully follow agronomic recommendations results in an inadequate stand of temporary vegetation that provides little or no erosion control.

Installation

Tillage

If the area has been recently plowed, no tillage is required other than raking or surface roughening to break any crust that has formed leaving a textured surface. Disk the soil for optimal germination when the soil is compacted less than 6-inches.

Soil Testing

Soil testing is available through Clemson University Cooperative Extension Service.

Lime

Lime is not required for temporary seeding unless a soil test shows that the soil pH is below 5.0. It may be desirable to apply lime during the temporary seeding operation to benefit the long-term permanent seeding. Apply a minimum of 1.5 tons of Lime/acre (70 pounds per 1000 square feet) if it is to be used.

Fertilizer

Apply a minimum of 500 pounds per acre of 10-10-10 fertilizer (11.5 pounds per 1000 square feet) or equivalent during temporary seeding unless a soil test indicates a different requirement. Incorporate fertilizer and lime (if used) into the top 4-6 inches of the soil by disking or other means where conditions allow.

Seeding

Loosen the soil surface before broadcasting the seed. Apply seed evenly by the most convenient method available for the type of seed used and the location of the temporary seeding. Typical application methods include but are not limited to cyclone seeders, rotary spreaders, drop spreaders, broadcast spreaders, hand spreaders, cultipacker seeder, and hydro-seeders. Cover applied seed by raking or dragging a chain, and then lightly firm the area with a roller or cultipacker.

Mulching

Use mulch with temporary seed applications to retain soil moisture and reduce erosion during the establishment of vegetation. Typical mulch applications include straw, wood fiber, hydromulches, BFM and FGM. Use hydromulches with a minimum blend of 70% wood fibers.

The most commonly accepted mulch used in conjunction with temporary seeding is small grain straw. This straw should be dry and free from mold damage and noxious weeds. The straw may need to be anchored with netting or emulsions to prevent it from being blown or washed away. Apply the straw mulch by hand or machine at the rate 1.5-2 tons per acre (90 pounds per 1000 square feet). Frequent inspections are necessary to check that conditions for growth are good.

Irrigation

Seeded areas should be kept adequately moist. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Re-seeding

Re-seed areas where seeding does not grow quickly, thick enough, or adequately to prevent erosion. Base seed selection should on the requirements of local Specifications.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Cover seeded with mulch to provide protection. Frequent inspections are necessary to check that conditions for growth are good.
- Supply temporary seeding with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Control water application rates to prevent runoff.

- Base seed selection on local Specifications.
- Re-seed areas where the plants do not grow quick enough, thick enough, or adequately enough to prevent erosion should be re-seeded.

Temporary Seeding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope was improperly dressed before application.	Roughen slopes. Furrow along the contour of areas to be seeded.
Coverage is inadequate.	Follow recommended application rates. Count the number of seedbags to ensure the correct amount of material is being applied. Reapply to thin areas.
Seeds fail to germinate.	Apply straw mulch to keep seeds in place and to moderate soil moisture and temperature. In arid areas, temporary irrigation may be necessary.
Seeded slope fails.	Fill in rills and re-seed; fertilize, and mulch slopes.
Seeding is washed off slope.	Allow at least 24-hours for the materials to dry before a rain event. Follow manufacturer's recommendations. Reapply where necessary.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area and to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Mulching

Plan Symbol

Description

Mulching is a temporary soil stabilization erosion control method where materials such as grass, hay, wood chips, wood fibers, or straw are placed on the soil surface. In addition to stabilizing soils, mulching enhancse the absorption of water by the soil, reduce evaporation losses, regulate soil temperatures, and reduce the speed of storm water runoff over an area.

When and Where to Use It

Use erosion control mulching on level areas or on slopes up to 50 percent. Where soil is highly erodible, nets should only be used in connection with organic mulch such as straw and wood fiber.

Mulch is an effective ground cover when the establishment of vegetation is improbable due to severe weather conditions (winter conditions), poor soil, or steep slopes.

Installation

Grading is not necessary before mulching but may be required if vegetation is expected to grow.

Anchor loose hay or straw by applying tackifier, stapling netting over the top, or crimping with a mulch-crimping tool.

Effective use of netting and matting material requires firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

Materials that are heavy enough to stay in place (for example, bark or wood chips on flat slopes) do not need anchoring.

Apply hydro-mulch in spring, summer, or fall to prevent deterioration of mulch before vegetation becomes established.

There must be adequate coverage to prevent erosion, washout, and poor plant establishment. If an appropriate tacking agent is not applied, or is applied in insufficient amounts, mulch is lost to wind and runoff.

Inspection and Maintenance

- Inspect every 7 calendar days and within 24-hours after each rainfall event that produces ½-inches or more of precipitation.
- Repair or replace damaged areas of mulch or tie-down material immediately.

Straw Mulch

Straw Mulch with Tackifier

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Mulch blows away.	Anchor straw mulch in place by applying a tackifier, crimping, punching, or track walking. May need to use a different BMP.
Coverage is inadequate.	Follow recommended application rates. Ensure that the correct amount of material is implemented. Reapply as necessary.
Mulch has washed away.	Do not place mulch in concentrated flow areas. Reapply as necessary.
Area was improperly dressed before application.	Remove existing vegetation and roughen embankment and fill areas by rolling with a punch type roller or by track walking.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow onto stabilized area and/or to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Erosion Control Blankets (ECBs)

Plan Symbol

Description

Temporary erosion control blankets (ECBs) are products composed primarily of biologically, photochemically or otherwise degradable constituents such as wheat straw, coconut fiber, or aged curled excelsior wood product with longevity of approximately 1- to 3-years.

When and Where to Use It

ECBs are used for the temporary stabilization of soil immediately following seeding until the vegetative cover has grown and becomes established. ECBs provide temporary protection by degrading over time as the vegetation becomes established. Some products are effective for a few months while others degrade slowly and are effective for up to 3-years.

ECB Categories

- Class A (Slope Applications Only)
- Class B (Channel Applications Only).

Class A ECBs are for **slope applications only**.

- Applicable for slopes **2H:1V or flatter** only. Slopes greater than 2H:1V require Turf Reinforcement Matting (TRM).

Class B ECBs are for **channel applications**.

- Applicable for channels and concentrated flow areas with a maximum calculated shear stress **less than 1.75 lb/ft^2**. Channels and concentrated flow areas with design shear stresses greater than 1.75 lb/ft^2 require TRM

All acceptable Class A and Class B temporary erosion control blankets consisting of straw, coconut, or straw-coconut blends meet the following requirements:

- Utilize non-organic, photodegradable or biodegradable polypropylene netting.
- Consist of **double netted matting**, defined as matting with netting on both sides of the blanket. The top netting is degradable polypropylene with a maximum mesh opening of 0.75 inches by 0.75 inches. The bottom is degradable polypropylene with a maximum mesh opening of 0.5 inches by 0.5 inches.
- Be sewn on center a maximum of 2.0 inches

All acceptable Class A and Class B temporary erosion control blankets consisting of curled excelsior fibers meet the following requirements:

- Utilize non-organic, photodegradable or biodegradable polypropylene netting
- Consist of double netted matting. Double netted matting is matting with netting on both sides of the blanket. The degradable polypropylene top netting requires a maximum mesh opening of 1.0-inches by 1.0-inches, while the degradable polypropylene bottom netting requires a maximum mesh opening of 1.0-inches by 1.0-inches
- Consist of curled excelsior interlocking fibers with 80% of the fibers a minimum of 6-inches long
- Sewn on center a maximum of 4.0-inches.

Use Class A and Class B temporary erosion control blankets having the following Minimum Average Roll Values (MARV) for physical properties, as derived from quality control testing performed by a Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP) accredited laboratory:

- Minimum mass per unit area (ASTM D6475) of 6 oz/yd^2 (203 g/m^2)
- Minimum thickness (ASTM D6525) of 0.25-inches (6 mm)
- Minimum initial grab tensile strength (ASTM D6818) of 75 x 75 lb/ft. (1 x 1 kN/m)
- Minimum roll width of 48-inches (1.22 m)
- For Class B channel applications, a minimum unvegetated shear stress of 1.0 lb/ft^2 (48 N/m^2) based on short-term peak flow duration of 0.5 hour is required.

Installation

Grade and compact areas to be protected with ECBs as indicated on the plans.

Remove large rocks, soil clods, vegetation, and other sharp objects that could keep the ECB from intimate contact with subgrade.

Prepare seedbed by loosening 2 to 3 inches of soil above final grade.

The proper installation of ECBs is different for each product, therefore the recommended installation procedure from the specific manufacturer should be followed.

When requested, a Manufacturer's Representative may be required to be on-site to oversee and approve the initial installation of the ECB. When requested, a letter from the Manufacturer approving the contractor installation may be required.

Inspection and Maintenance

- Inspect areas protected by ECBs for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Conduct regular inspections until grasses are firmly established.
- Adhere to the pinning or stapling pattern as shown on the Manufacturer's installation sheet. If there is evidence that the ECB is not securely fastened to the soil, require extra pins or staples to inhibit the ECB from becoming dislodged.
- If washout or breakage occurs, repair all damaged areas immediately by restoring the soil on slopes or channels to its finished grade, re-apply fertilizer and seed, and replacing the appropriate ECB material as needed.

ECB Channel Design Criteria

The design of a permanent conveyance with a grassed or vegetative lining should address the bare condition prior to vegetation being established. An ECB will protect the conveyance during this period. Use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of ECBs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, select a corresponding ECB that meets the conditions from the SCDOT approved product list.

- The governing equation for maximum channel shear stress is:

$$\tau = \gamma \, d_n \, S$$

Where:

τ	=	maximum shear stress (lbs/ft^2)
γ	=	unit weight of water = 62.4 lbs/ft^3
d_n	=	maximum normal channel flow depth (ft)
S	=	channel bed slope (ft/ft)

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning's channel roughness coefficient (n) of the ECB from the following conditions:
  - Bare ECB with no vegetation,
  - ECB with maintained vegetation, and
  - ECB with un-maintained vegetation, and
- Normal channel flow depth (d_n) based on peak flow rate, channel dimensions and Manning's n value.

The governing equation for maximum velocity is Manning's Equation:

$$V = (1.49 / n) \; R^{2/3} \; S^{1/2}$$

Where :

V	=	Maximum velocity (ft/sec)
n	=	Manning's channel roughness coefficient
R	=	Hydraulic radius of the flow based on d_n (ft)
S	=	Channel bed slope (ft/ft)

ECB Slope Application

ECB Slope Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Undercutting occurs along the top of the slope.	Dig a 6-x 6-inch trench along the top of the slope and anchor blanket into trench by back filling and tamping the soil.
Blankets separate along the seams.	Overlap adjacent blanket 2- to 3-inch and staple every 3-feet.
Blankets separate where the rolls are attached end to end.	Shingle the blanket so the top blanket covers the bottom blanket by 6-inches and staple through the overlapped areas every 12-inches.
Blanket does not make complete contact with the soil surface.	Prepare the soil surface by removing rocks, clods, sticks and vegetation, fill in rill, and uneven areas.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Turf Reinforcement Mats (TRMs)

Plan Symbol

Description

Turf Reinforcement Mats are products composed primarily of nondegradable products that enhance the ability of living plants to stabilize soils. They bind with roots to reinforce the soil matrix with longevity greater than 5-years.

When and Where to Use It

Use TRMs where vegetation alone will not hold a slope or streambank. TRMs enable the use of "green" solutions in areas where only "hard" solutions such as riprap or concrete linings were viable in the past.

TRM Categories

- Type 1, Type 2, Type 3, and Type 4.

Types 1 & 2 TRMs are a strong three-dimensional stable net structure. A degradable fiber matrix may be included to provide immediate coverage for bare soil.

- **Type 1** matting should be placed on slopes **2H:1V or flatter** or in channels where the calculated design shear stress is **4.0 lb/ft2 or less** and the design flow velocity is **up to 10 fps**.
- **Type 2** matting should be placed on slopes **1.5H:1V or flatter** or in channels where the calculated design shear stress is **6.0 lb/ft2 or less** and the design flow velocity is **up to 15 fps**.
- **Type 3** TRMs are a strong three-dimensional stable net structure providing sufficient thickness, strength, and void space to capture and retain soil and allow for the development of root growth and vegetation within the matrix. Matting of this type should be placed on slopes **1H:1V or flatter** or in channels where the calculated design shear stress is **8.0 lb/ft2 or less** and the design flow velocity is **up to 20 fps**
- **Type 4** (High Survivability) TRMs are specially designed geosynthetics for erosion control applications on steep slopes and vegetated waterways.

  - All components of Type 4 TRMs should be 100% synthetic and resistant to biological, chemical, and ultraviolet degradation.

  - Matting of this type should be placed on slopes **1H:1V or greater** or in channels where the calculated design shear stress is **up to 12 lb/ft2** and the design flow velocity is **up to 25 fps**.

  - This category is used when field conditions exist with high loading and/or high survivability requirements such as maintenance, structural backfills protecting critical structures, utility cuts, potential traffic areas, abrasion, higher factors of safety and/or general durability concerns.

All primary TRM matrix materials are defined as long-term, non-degradable materials designed to reduce soil erosion and assist in the growth, establishment, and protection of vegetation for a period of time exceeding 5 years.
The major structural components of Type 1 and Type 2 TRMs are 100% synthetic and resistant to biological, chemical, and ultraviolet degradation. A degradable fiber matrix may be included to provide immediate coverage for bare soil. All components of Type 3 and Type 4 TRMs are 100% synthetic and resistant to biological, chemical, and ultraviolet degradation.

Installation

Grade and compact areas to be protected with TRMs as indicated on the plans.

Remove large rocks, soil clods, vegetation, and other sharp objects that could keep the TRM from intimate contact with subgrade.

Prepare seedbed by loosening 2 to 3 inches of soil above final grade.

The proper installation of TRMs is different for each product, therefore the recommended installation procedure from the specific manufacturer should be followed.

When requested, a Manufacturer's Representative may be required to be on-site to oversee and approve the initial installation of the TRM. When requested, a letter from the Manufacturer approving the contractor installation may be required.

Inspection and Maintenance

- Check areas protected by TRMs for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Conduct regular inspections until grasses are firmly established.
- Adhere to the pinning or stapling pattern as shown on the Manufacturer's installation sheet. If there is evidence that the TRM is not securely fastened to the soil, install extra pins or staples to inhibit the TRM from becoming dislodged.
- If washout or breakage occurs, repair all damaged areas immediately by restoring the soil on slopes or channels to its finished grade, re-apply fertilizer and seed, and replacing the appropriate TRM material as needed.

TRM Channel Design Criteria

When designing a permanent conveyance with a grassed or vegetative lining, the design should address the bare condition prior to vegetation being established. A geotextile lining may be applied to protect the conveyance during this period. It is important to use both the tractive force and the permissible velocity methods to determine the level of protection that is required.

The design of TRMs is based on the anticipated shear stresses and maximum flow velocities the fabric will encounter. Once the design shear stresses and maximum flow velocities are known, a corresponding TRM that meets the conditions may be selected from the SCDOT approved products list.

- The governing equation for maximum channel shear stress is:

$$\tau = \gamma \, d_n \, S$$

Where :

τ	=	maximum shear stress (lbs/ft^2)
γ	=	unit weight of water = 62.4 lbs/ft^3
d_n	=	maximum normal channel flow depth (ft)
S	=	channel bed slope (ft/ft)

The following variables are required to determine the maximum velocity in a channel for a 10-year 24-hour storm event.

- Design peak flow rate value in cubic feet per second (cfs) for the 10-year 24-hour storm,
- Channel dimensions designed to carry the peak flow rate. For simplicity, all channels will be assumed to be trapezoidal in shape,
- Channel bed slope,
- Manning's channel roughness coefficient (n) of the TRM based on the following,
  - Bare matting with no vegetation,
  - Matting with maintained vegetation, and
  - Matting with un-maintained vegetation, and
- Normal channel flow depth (d_n) based on peak flow rate, channel dimensions, and Manning's n value.

- The governing equation for maximum velocity is Manning's Equation:

$$V = (1.49 / n) \; R^{2/3} \; S^{1/2}$$

Where :

V	=	Maximum velocity (ft/sec)
n	=	Manning's channel roughness coefficient
R	=	Hydraulic radius of the flow based on d_n (ft)
S	=	Channel bed slope (ft/ft)

TRM Slope Application

TRM Channel Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Improper anchoring.	Dig trench along the top and bury the blankets. Use staples to anchor according to manufacturer's recommendations.
Undercutting due to inadequate preparation.	Prepare the soil surface. Remove rocks, clods, and other obstructions. Fill in rills in uneven areas to promote good contact between mat and soil.
Excessive water flows across stabilized slope surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize areas with swift moving concentrated flows.

Flexible Growth Media/Matrix

Plan Symbol

Description

A Flexible Growth Matrix (FGM) combines both chemical and mechanical bonding techniques to lock the matrix in place. FGM is composed of crimped, manmade fibers, organic fibers, and performance-enhancing additives that form a lofty, interlocking matrix. FGM has air spaces and water-absorbing cavities that improve seed germination, reduce the impact of raindrop energy, and minimize soil loss. Water insoluble tackifiers and flocculants chemically bond the matrix to the soil surface.

When and Where to Use It

FGM is applicable for the following situations:

- As a Type A Temporary Erosion Control Blanket
- Slopes up to 2H:1V
- As an infill for TRMs on slopes greater than 2H:1V
- Environmentally sensitive areas not compatible for netting
- When the required longevity of soil protection is up to 1 year
- When the site requires immediate erosion protection and there is a risk of impending weather
- When fast vegetation establishment is required
- When a high factor of design safety is required.

FGM is **not** applicable as a channel liner or for areas receiving concentrated flow. Applicable FGM may be selected from the SCDOT approved products list.

Installation

All FGM components are pre-packaged by the Manufacturer to assure material performance. Under no circumstances is field mixing of materials, additives or components accepted. Examine substrates and conditions where materials will be applied. Apply FGM to geotechnically stable slopes that have been designed and constructed to divert runoff away from the face of the slope. Do not proceed with installation until satisfactory conditions are established.

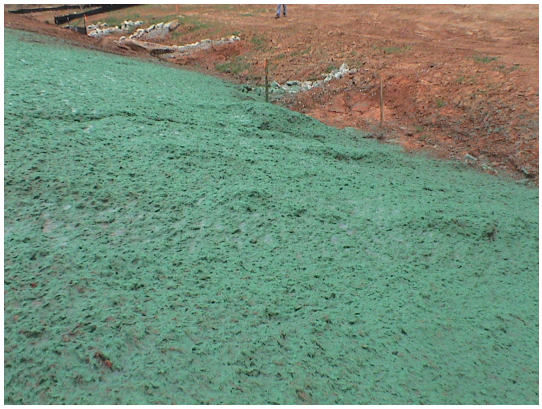
Install FGM with a contractor who is certified and trained by the Manufacturer in the proper procedures for mixing and applying the FGM. Strictly comply with the Manufacturer's mixing recommendations and installation instructions. Use approved hydraulic seeding/mulching machines with fan-type nozzle (50-degree tip) for FGM applications. Apply FGM from opposing directions to the soil surface in successive layers, reducing the "shadow effect" to achieve maximum coverage of all exposed soil. FGM does not require a cure time and is effective immediately such that FGM may be applied immediately before, during or after a rainfall event. Install FGM materials according to the Manufacturer's application rates.

Inspection and Maintenance

- Check areas protected by FGM for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Reapply FGM to disturbed areas that require continued erosion control.

- Maintain equipment to provide uniform application rates. Rinse all mixing and application equipment thoroughly with water to avoid formation of residues and discharge rinse water appropriately.
- Degradation of FGM is expected to occur as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply FGM in accordance with the Manufacturer's instructions. Reapplication is not required unless FGM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

FGM Application



FGM

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope areas have eroded due to concentrated flows.	Make sure the upper end of the slope has a berm constructed to eliminate concentrated flows from flowing down the slope. Slope length may be too long and concentrated flows are occurring. Use sediment tubes or other practices to provide slope breaks. Re-apply FGM to the eroded areas once the concentration problem has been resolved.
Rain event is impending.	FGM does not require a cure time and is effective immediately such that FGM may be applied immediately before, during or after a rainfall event.
FGM has degraded.	FGM has a longevity of soil protection up to 1 year. In some instances degradation of FGM occurs as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply FGM in accordance with the Manufacturer's instructions. Reapplication is not required unless FGM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

Bonded Fiber Matrix (BFM)

Plan Symbol

Description

A Bonded Fiber Matrix (BFM) is a continuous layer of non-toxic, degradable, elongated fiber materials held together by water insoluble bonding agents. BFM eliminates direct raindrop impact on soil, allows no gaps between the product and the soil, and has a high water-holding capacity. BFMs do not form a water-insensitive crust that can inhibit plant growth. BFMs are completely photo- and biodegradable.

When and Where to Use It

BFMs are applicable when:

- Enhancement of temporary seeding operations to reduce erosion and expedite seed germination
- A high performance mulch is required for permanent seeding
- Seeding application will take place on highly erodible soil or slopes
- Slopes up to 1H:1V
- The required functional longevity of soil protection is 6 months or less
- The soil is dry and rain is not expected within 48 hours after application
- There is a high degree of certainty that heavy rains will not follow application.

BFMs are **not** applicable as Type A Temporary Erosion Control Blankets, channel liners or for areas receiving concentrated flow. Applicable BFM may be selected from the SCDHEC approved products list.

Installation

All BFM components are pre-packaged by the Manufacturer to assure material performance. Under no circumstances is field mixing of materials, additives or components accepted. Examine substrates and conditions where materials will be applied. Do not proceed with installation until unsatisfactory conditions are corrected. Apply BFM to geotechnically stable slopes that have been designed and built to divert runoff water away from the face of the slope, eliminating damage to the slope face caused by the surface flow from above the slope.

Install BFM with a contractor who is certified and trained by the Manufacturer in the proper procedures for mixing and applying the BFM. Strictly comply with the Manufacturer's mixing recommendations and installation instructions. Use approved hydraulic seeding/mulching machines with fan-type nozzle (50-degree tip) for BFM applications. Apply BFM from opposing directions to the soil surface in successive layers, reducing the "shadow effect" to achieve maximum coverage of all exposed soil. Do not apply the BFM immediately before, during or after rainfall. Allow the BFM a minimum of 24 hours to dry after installation. Do not exceed maximum slope length of 100 feet when slope gradients are steeper than 4H:1V. Install BFMs at a general application rate of 3500 pounds per acre.

Inspection and Maintenance

- Check areas protected by BFM for dislocation or failure every 7 calendar days and within 24-hours after each storm that produces ½-inch or more of rain.
- Reapply BFM to disturbed areas that require continued erosion control.
- Maintain equipment to provide uniform application rates.

- Rinse all BFM mixing and application equipment thoroughly with water to avoid formation of residues and discharge rinse water appropriately.
- Degradation of BFM is expected to occur as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply BFM in accordance with the Manufacturer's instructions. Reapplication is not required unless BFM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

BFM Application

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope areas have eroded due to concentrated flows.	Make sure the upper end of the slope has a berm constructed to eliminate concentrated flows from flowing down the slope. Slope length may be too long and concentrated flows are occurring. Use sediment tubes or other practices to provide slope breaks. Re-apply BFM to the eroded areas once the concentration problem has been resolved.
Rain event is impending.	BFM requires a cure time. Do not apply the BFM immediately before, during or after rainfall. Allow the BFM a minimum of 24 hours to dry after installation.
BFM has degraded.	BFM has longevity of soil protection up to 6-months. In some instances degradation of BFM occurs as a result of mechanical degradation, chemical and biological hydrolysis, sunlight, salt and temperature. Reapply BFM in accordance with the Manufacturer's instructions. Reapplication is not required unless BFM treated soils are disturbed or turbidity or water quality shows the need for an additional application.

Permanent Seeding

Plan Symbol

Description

Controlling runoff and preventing erosion by establishing a perennial vegetative cover with seed.

When and Where to Use It

A major consideration in the selection of the type of permanent grass to establish is the intended use of the land. Land use is separated in to two categories, high-maintenance and low-maintenance.

High-maintenance

High maintenance areas are mowed frequently, lime or fertilized on a regular basis, and require maintenance to an aesthetic standard. Land uses with high maintenance grasses include homes, industrial parks, schools, churches, and recreational areas such as parks, athletic fields, and golf courses.

Low-maintenance

Low maintenance areas are mowed infrequently, if at all, and lime and fertilizer may not be applied on a regular schedule. These areas are not subject to intense use and do not require a uniform appearance. The vegetation must be able to survive with little maintenance over long periods of time. Grass and legume mixtures are favored in these areas because legumes are capable of fixing nitrogen in the soil for their own use and the use of the grasses around them. Land uses requiring low-maintenance grasses include steep slopes, stream and channel banks, road banks, and commercial and industrial areas with limited access.

Seed Selection

The use of native species is preferred when selecting vegetation. Base plant seed selection on geographical location, the type of soil, the season of the year in which the planting is to be done, and the needs and desires of the permanent land user. Failure to carefully follow agronomic recommendations results in an inadequate stand of permanent vegetation that provides little or no erosion control.

Installation

Topsoil

Apply topsoil if the surface soil of the seedbed is not adequate for plant growth.

Tillage

If the area has been recently plowed, no tillage is required other than raking or surface roughening to break any crust that has formed leaving a textured surface. Disk the soil for optimal germination when the soil is compacted less than 6-inches. If the soil is compacted more than 6-inches, sub-soiled and disk the area.

Soil Testing

Soil testing is available through Clemson University Cooperative Extension Service.

Lime

Unless a specific soil test indicates otherwise, apply 1½ tons of ground course textured agricultural limestone per acre (70 pounds per 1000 square feet).

Fertilizer

Apply a minimum of 1000 pounds per acre of a complete 10-10-10 fertilizer (23 pounds per 1000 square feet) or equivalent during permanent seeding of grasses unless a soil test indicates a different requirement. Incorporate fertilizer and lime (if used) into the top 4-6 inches of the soil by disking or other means where conditions allow. Do not mix the lime and the fertilizer prior to the field application.

Seeding

Loosen the surface of the soil just before broadcasting the seed. Evenly apply seed by the most convenient method available for the type of seed applied and the location of the seeding. Typical application methods include but are not limited to cyclone seeders, rotary spreaders, drop spreaders, broadcast spreaders, hand spreaders, cultipacker seeder, and hydro-seeders. Cover applied seed by raking or dragging a chain or brush mat, and then lightly firm the area with a roller or cultipacker. Do not roll seed that is applied with a hydro-seeder and hydro-mulch.

Mulching

Cover all permanent seeded areas with mulch immediately upon completion of the seeding application to retain soil moisture and reduce erosion during establishment of vegetation. Apply the mulch evenly in such a manner that it provides a minimum of 75% coverage. Typical mulch applications include straw, wood fiber, hydromulches, BFM and FGM. Use hydromulches with a minimum blend of 70% wood fibers.

The most commonly accepted mulch used in conjunction with permanent seeding is small grain straw. Select straw that is dry and free from mold damage and noxious weeds. The straw may need to be anchored with netting or asphalt emulsions to prevent it from being blown or washed away. Apply straw mulch by hand or machine at the rate 2 tons per acre (90 pounds per 1000 square feet). Frequent inspections are necessary to check that conditions for growth are good.

Irrigation

Keep permanent seeded areas adequately moist, especially late in the specific growing season. Irrigate the seeded area if normal rainfall is not adequate for the germination and growth of seedlings. Water seeded areas at controlled rates that are less than the rate at which the soil can absorb water to prevent runoff. Runoff of irrigation water wastes water and can cause erosion.

Re-seeding

Inspect permanently seeded areas for failure, make necessary repairs and re-seed or overseed within the same growing season if possible. If the grass cover is sparse or patchy, re-evaluate the choice of grass and quantities of lime and fertilizer applied. Final stabilization by permanent seeding of the site requires that it be covered by a 70% coverage rate.

Inspection and Maintenance

- Inspect seeded areas for failure and make necessary repairs and re-seed immediately. Conduct a follow-up survey after one year and replace failed plants where necessary.
- If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.
- If a stand of permanent vegetation has less than 40 percent cover, re-evaluate choice of plant materials and quantities of lime and fertilizer.
- Re-establish the stand following seed bed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results.
- If the season prevents re-sowing, mulch is an effective temporary cover.
- Final stabilization of the site requires a 70 percent overall coverage rate. This does not mean that 30 percent of the site can remain bare. The coverage is defined as looking at a square yard of coverage, in which 70 percent of that square yard is covered with vegetation.

Permanent Seeding

Permanent Seeding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Areas have eroded.	Re-seed or replace eroded areas.
Vegetation cover is inadequate and rill erosion is occurring.	Overseed and fertilize in accordance with soil test results.
Stand of permanent vegetation has less than 40% cover.	Re-evaluate choice of plant materials and quantities of lime and fertilizer.
Vegetation show signs of wilting before noon.	Water vegetation by wetting soil to a depth of 4-inches.

Sodding

Plan Symbol

Description

Sodding is transplanting vegetative sections of plant materials to promptly stabilize areas that are subject to erosion. Use commercial sod which is a cultured product utilizing specific grass species.

When and Where to Use It

Sodding is appropriate for any graded or cleared area that may erode, and where a permanent, long-lived plant cover is immediately needed. Examples of where sodding is used are yards, buffer zones, streambanks, dikes, swales, slopes, outlets, level spreaders, and filter strips.

Installation

In general, do not use sod on slopes greater than 2H:1V or 3H:1V if it is to be mowed. If sod is placed on steep slopes, lay it with staggered joints and/or staple the sod down.

Clear the soil surface of trash, debris, roots, branches and soil clods in excess of 2-inches length or diameter. Rake soil surface to break crust just before laying sod or irrigate soil lightly if the soil is dry. Do not install sod on hot, dry or frozen soil, gravel, compacted clay, or pesticide treated soils.

Harvest, deliver and install sod within a period of 36-hours. Store rolls of sod in shade during installation. Sod should be free of weeds and be of uniform thickness, about 1-inch, and should have a dense root mat for mechanical strength.

Lay strips of sod beginning at the lowest area to be sodded with the longest dimension of the strip perpendicular to the slope, and stagger in a brick-like pattern. Wedge strips securely in place. Square the ends of each strip to provide for a close, tight fit. Match angled ends correctly to prevent voids.

Roll or compact immediately after installation to ensure firm contact with the underlying topsoil.

Irrigate the sod until the soil is wet to a depth of 2-inches, and keep moist until grass takes root.

Inspection and Maintenance

- Watering may be necessary after planting and during periods of intense heat and/or lack of rain (drought). Keep soil moist to a depth of 2-inches until sod is fully rooted.
- Mow to a height of 2 to 3 inches after sod is well-rooted (2-3 weeks). Do not remove more than 1/3 of the shoot in any one mowing.
- Permanent, fine turf areas require yearly applications of fertilizer and lime.
- Inspect the sod frequently after it is first installed, especially after large storm events, until it has established a permanent cover.

Sodding

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Drought	Keep soil moist to a depth of 2-inches until sod is fully rooted

Riprap

Plan Symbol

Description

Riprap is a permanent, erosion-resistant channel lining aggregate consisting of large, loose, angular stone with a filter fabric or granular underlining. The purpose of riprap is to:

- Protect the soil from the erosive force of concentrated runoff
- Slow runoff velocities while enhancing the potential for infiltration

The filter fabric or granular underlining prevents undermining of the riprap layer by the migration of soil particles under seepage forces through the riprap.

When and Where to Use It

The preferred method of slope and channel protection is the use of vegetation. If vegetation can not withstand the design flows, ECBs and TRMs are the preferred and suggested method of protection. When conditions are too severe for vegetation and TRMs, riprap may be used for erosion control and protection. Riprap is used, as appropriate, at storm drain outlets, on channel banks and/or bottoms, drop structures, at the toe of slopes, and in transitions from concrete channels to vegetated channels. Riprap sizes are designed by the diameter or by the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be angular instead of spherical.

Installation

Place a lining of geotextile filter fabric or granular filter material between the riprap and the underlying soil surface to prevent soil movement into or through the riprap.

Inspection and Maintenance

- Once a riprap installation has been completed, it should require very little maintenance.
- It should, however, be inspected periodically to determine if high flows have caused scour beneath the riprap and filter fabric or dislodged any of the stone.
- Care must be taken to properly control sediment-laden construction runoff that may drain to the point of the new installation. If repairs are needed, they should be performed immediately.

Riprap Design Criteria

Riprap at Outlets

Design criteria for sizing the stone and determining the dimensions of riprap pads used at the outlet of drainage structure are given in the Outlet Protection section of this Manual**.**

Riprap for Channel Stabilization

Design of erosion protection within the channel can be accomplished using the FHWA Tangent Flow Method presented below. This method is applicable to both straight and curved channel sections where flows are tangent to channel bank. The Tangent Flow Method determines a stable rock size for straight and curved channel sections using known shape, flow depth, and channel slope dimensions. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3H:1V, the stone size must be modified. The final design size will be stable on both the sides and bottom of the channel.

Straight Channel Sections

1. Refer to the graph shown in Figures RR1 with the maximum flow depth (**d** in feet) and channel slope (ft/ft). Select the point where the maximum flow depth and channel slope intersect. Choose the $\mathbf{d_{50initial}}$ stone size based upon the location of the point of intersection.

2. This completes the design procedure for channels with side slopes 3H:1V and flatter. If the channel side slopes are steeper than 3H:1V, continue with step 3.

3. Refer to the graph shown in Figure RR2 with the side slope (**Z** in H:V) and the base width **(B)** to maximum depth **(d)** ratio **(B/d)**. Where the two lines intersect, move horizontally left to read $\mathbf{K_1}$.

4. Determine from the graph in Figure RR3 the angle of repose for the $\mathbf{d_{50initial}}$ stone size and the channel side slope **Z**. (Use an angle of 42^o for $\mathbf{d_{50initial}}$ >10-inches. Do not use riprap on slopes steeper than the angle of repose for the stone size.)

5. Refer to the graph shown in Figure RR4 with the side slope **(Z)** of the channel and the angle of repose for the $\mathbf{d_{50initial}}$ stone size. Where the two lines intersect, move vertically down to read $\mathbf{K_2}$.

6. Compute $\mathbf{d_{50initial} \times K_1/K_2 = d_{50design}}$ to determine the correct size stone for the bottom and side slopes of straight sections of channel.

Curved Channel Sections

1. Refer to steps 1-6 under Straight Channel Sections
2. Determine the radius of the curved section $\mathbf{(R_O)}$ in feet.
3. Calculate the top width of the riprap at the design water surface $\mathbf{(B_S)}$ in feet

   B_S = $B_O + 2(Z*D)$

   B_O = Bottom width of channel (feet)

   Z = Channel sides slopes defined as ZH:1V

   D = Depth of riprap (feet)
4. Calculate the Ratio $\mathbf{B_S / R_O}$
5. Knowing the value of the $\mathbf{B_S/R_O}$ ratio from step 4, use the graph in Figure RR5 and read the corresponding value of $\mathbf{K_3}$.
6. Compute $\mathbf{(d_{50design} \times K_3) = d_{50curve}}$ to determine the correct size stone for the bottom and side slopes of curved channel sections.

Straight Channel Design Example

Given: Trapezoidal channel depth (D) 3-feet, bottom width (B_o) 8-feet, side slopes (Z) 2H:1V, and a 2 percent slope.

Find: A stable riprap size for the bottom and side slopes of the channel.

Solution:

1. From Figure RR1, for a 3-foot-deep channel over a 2 percent grade,
   Read $d_{50initial}$ = 0.75-feet or 9-inches.

2. Since the side slopes are steeper than 3H:1V, continue with step 3
   **If side slopes were less than 3H:1V, the process would be complete.

3. From Figure RR2, $B_O/d = 8/3 = 2.67$, Side slopes Z = 2,
   Read $K_1 = 0.82$.

4. From Figure RR3, for $d_{50initial}$ = 9-inches,
   Read Angle of Repose = 41

5. From Figure RR4, side slopes Z = 2, and Angle of Repose = 41 ,
   Read $K_2 = 0.73$.

6. Stable Riprap = $d_{50design} \times (K_1/K_2) = 0.75 \times (0.82/0.73) = 0.84$-feet or 10-inches

Curved Channel Design Example

Given: The preceding straight channel example has a curved section with a radius of 50-feet.

Find: A stable riprap size for the bottom and side slopes of the curved channel section.

Solution:

1. Stable Riprap = $d_{50design}$ 10-inches from straight channel calculations.

2. R_O = 50-feet.

3. Calculate Channel Top Width of Water Surface
   $B_S = B_O + 2(Z*D) = 8 + 2(2*3) = 20$-feet.

4. Calculate the Ratio B_S / R_O
   $= 20/50 = 0.40$

5. From Figure RR5, for $B_S / R_O = 0.40$
   Read $K_3 = 1.1$

6. $d_{50curve} = d_{50design} \times K_3 = (0.84\text{-ft.} \times 1.1) = 0.92$-feet or 11-inches.

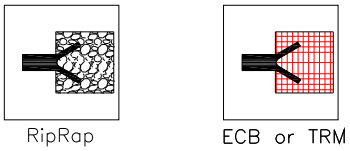
Riprap Lined Channel

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
High flows causing scour beneath riprap or filter fabric dislodging the stone.	Replace filter fabric and rearrange stone appropriately.
Riprap blocks channel, causing erosion along edges.	Make sure excavation is deep enough, rearrange riprap appropriately.
Piping or slumping occurs.	Make sure filter fabric was installed and make sure it isn't damaged.
Stones have moved and erosion of foundation has occurred.	Make sure riprap is properly graded.
Undercut riprap slope and slumping occurring.	Check to be sure that foundation toe is properly reinforced.
Stone displacement occurring.	Make sure fill slopes have been properly compacted, remove debris and make needed repairs.

Outlet Protection

Plan Symbol



Description

Outlet protection dissipates the energy of concentrated storm water flows reducing erosion or scouring at storm water outlets. In addition, outlet protection lowers the potential for downstream erosion. Outlet protection is achieved through a variety of techniques, including turf reinforcement mats (TRMs), riprap, concrete aprons, paved sections and other structural measures.

The techniques outlined in this section are not the only techniques that may be used for outlet protection design. This section shows one method for outlet protection design as an example of the variables that need to be considered in the design. Other methods utilized that are not discussed in this Handbook should include all graphs, charts, and calculations verifying that the protection will handle the peak flow velocity, flow depths, and shear stress.

Outlet Protection Design Criteria

The design of outlets for pipes and channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10 percent should not be protected using just outlet protection. This causes re-concentration of the flow resulting in increased velocities when the flow leaves the protection area. Outlet protection may be designed according to the following criteria:

1. The design flow velocity exiting the outlet at design capacity **should not** exceed the permissible velocity of receiving area.

2. Tailwater Depth:
   Tailwater is the water depth at the downstream end or outfall of the culvert. The depth of tailwater immediately below the outlet protection must be determined for the design capacity of the pipe.

   Minimum Tailwater Condition is defined as a tailwater depth less than ½ the diameter of the outlet pipe. Pipes that outlet onto flat areas with no defined channel have a minimum tailwater condition.

   Maximum Tailwater Condition is defined as a tailwater depth greater than ½ the pipe diameter.

3. Protection Length:
   The required protection length, L_a, according to the tailwater condition, should be determined from Figure OP1(minimum tailwater condition) or Figure OP2 (maximum tailwater condition).

4. Protection Width: When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the Maximum Tailwater depth or to the top of the bank (whichever is less).

- If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined with a Minimum Tailwater Condition:

  Design the upstream end of the protection, adjacent to the outlet, with a width three times the diameter of the outlet pipe (3D). Design the downstream end of the protection with a width equal to the pipe diameter plus the length of the apron ($D + L_a$).

- For a Maximum Tailwater Condition, design the downstream end of the protection with a width equal to the pipe diameter plus 0.4 times the length of the apron ($D + 0.4 * L_a$).

5. Bottom Grade: Construct the protection with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection is equal to the elevation of the invert of the receiving channel. There is no overfalling at the end of the protection.

6. Side Slopes: If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

7. Alignment: Locate the protection so there are no bends in the horizontal alignment.

8. Materials:

- The preferred protection lining is an appropriate permanent turf reinforcement matting (TRM). Calculate the shear stress and maximum velocity to determine the applicable TRM.
- When conditions are too severe for TRMs the protection may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median-sized stone for riprap may be determined from design figures according to the tailwater condition.
- In all cases, place a non-woven geotextile filter cloth between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the required physical properties for filter cloth.

Installation

- Do not protect pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% with only outlet protection. This causes re-concentration of the flow that results in large velocities when the flow leaves the protection area.
- Follow specific standards for installation of the selected materials used for outlet protection.
- Follow all Manufacturer's installation procedures for TRMs and other manufactured products.
- A Manufacturer's Representative may be required to oversee all installation procedures and officially approve the installation of manufactured products used for outlet protection.

Inspection and Maintenance

- Periodically check all outlet protection, aprons, plunge pools, and structural outlets for damage. Immediately make all needed repairs to prevent further damage.
- If any evidence of erosion or scouring is apparent, modify the design as needed to provide long term protection (keeping in mind fish passage requirements if applicable).
- Inspect outlet structures after heavy rains to see if any erosion has taken place around or below the structure.

Outlet Protection Design Example

Given: An 18-inch pipe discharges 24 cfs at design capacity onto a grassy slope (no defined channel).
Find: The required length, width, and median stone size (d_{50}) for riprap lined protection.
Solution:

1. The pipe discharges onto a grassy slope with no defined channel, a **Minimum Tailwater Condition**.

2. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches, Gives a protection length (L_a) of 20-feet.

3. From Figure OP1, the intersection of a discharge of 24 cfs and a pipe diameter **(d)** of 18-inches. Gives a median stone size (d_{50}) of 0.8-ft.

4. The upstream protection width equals 3 times the pipe diameter ($3D_o$) = 3 x 1.5-feet = 4.5-feet

5. The downstream protection width equals apron length (L_a)+ pipe diameter **(d)** ; = 20-feet + 1.5-feet = **21.5-feet**

The table below provides general information for sizing rock and outlet aprons for various sized pipes

Pipe Size (inches)	Average Rock Diameter (inches)	Apron Width (feet)	Apron Length for Low Flow (feet)	Apron Length for High Flow (feet)
8	3	2-3	3-5	5-7
12	5	3-4	4-6	8-12
18	8	4-6	6-8	12-18
24	10	6-8	8-12	18-22
30	12	8-10	12-14	22-28
36	14	10-12	14-16	28-32
42	16	12-14	16-18	32-38
48	20	14-16	18-25	38-44

Riprap Outlet Protection

Riprap Outlet Protection

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Riprap washes away.	Replace riprap with a larger diameter stone based on the pipe diameter and discharge velocity.
Apron is displaced.	Align apron with receiving water and keep it straight throughout its length. Repair damaged fabric and/or replace riprap that has washed away.
Scour occurs around apron or riprap.	Remove damaged TRM or riprap, fill in scoured areas, and repair damage to slopes channels or underlying filter fabric. Reinstall outlet protection.
Outlet erodes.	Stabilize TRM outlets with vegetation, replace eroded riprap; grout riprap.

Dust Control

Plan Symbol

Description

Wind erosion occurs when the surface soil is loose and dry, vegetation is sparse or absent, the wind is sufficiently strong, and when construction traffic disturbs the soil. Wind erodes soils and transports the sediment off site in the form of fugitive dust, where it may be washed into receiving water bodies by the next rainfall event. Fugitive dust is a nuisance for neighbors. It settles on automobiles, structures and windows and finds its way into homes. It also makes breathing difficult for those with respiratory problems and becomes a safety problem when it blinds motorists, equipment operators, and laborers.

When and Where to Use It

Utilize dust control methods whenever there are offsite impacts, especially during periods of drought. Implemented dust control until final stabilization is reached.

Dust Control Design Criteria

There are many methods to control dust on construction sites. These methods include but are not limited to :

- Phasing the Project. Phasing is done to decrease the area of disturbed soil that is exposed to erosion. The smaller the amount of soil that is exposed at one time, the smaller the potential for dust generation. Phasing a project and utilizing temporary stabilization practices can significantly reduce dust emissions.
- Vegetative Cover. A vegetative cover helps reduce wind erosion. Vegetative Cover is for disturbed areas not subject to traffic. Vegetation provides the most practical method of dust control.
- Mulch. Mulching offers a temporary way to stabilize the soil and prevent erosion. Mulching offers a fast, effective means of controlling dust.
- Sprinkling Water. Sprinkling helps control the suspension of dust particles and promotes dust to settle out of the air. Sprinkling water is effective for dust control on haul roads and other traffic routes.
- Spray-on-Adhesive. Adhesives prevent soil from blowing away. Latex emulsions, or resin in water is sprayed onto mineral soils to prevent their blowing away and reduce dust caused by traffic.
- Calcium Chloride. Calcium chloride keeps the soil surface moist and prevents erosion. Calcium chloride is applied by mechanical spreaders as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.
- Barriers. Barriers are fences that prevent erosion by obstructing the wind near the ground stopping the soil from blowing offsite. Broad, wind, or sediment fences can control air currents and blowing soil. Barriers are not a substitute for permanent stabilization. Perennial grass and strands of existing trees may also serve as wind barriers.

Inspection and Maintenance

- Add additional dust control or re-spray area as necessary to keep dust to a minimum.
- Spray exposed soil areas only with approved dust control agents as indicated by the SCDHEC Standard Specifications.

Dust Control by Sprinkling Water

Dust Control by Sprinkling Water

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Excessive dust leaves the site.	Increase frequency of dust control application. Consider using a palliative or binder on inactive areas.
Vehicles kick up dust.	Water more frequently. Limit vehicle speeds. Stabilize the roadway.
Watering for dust control causes erosion.	Reduce water pressure on the water truck. Check watering equipment to ensure that it has a positive shutoff. Water less frequently.
Sprayed areas are ineffective at limiting dust.	Re-spray areas and ensure that the application rate is proper. Try another product or method if current dust control is not effective.

Polyacrylamides (PAMs)

Plan Symbol

Description

Anionic polyacrylamides (PAM) are non-toxic chemical materials used for controlling soil erosion and sedimentation on construction and agricultural sites.

When and Where to Use It

Anionic PAM is available in emulsions, powders, gel bars, or logs. It is recommended that other BMPs be used in combination with anionic PAM. The use of seed and mulch for additional erosion protection beyond the life of the anionic PAM is required. Repeat application is recommended if disturbance occurs to target areas. The following are additional recommendations:

- Use setbacks when applying anionic PAM near natural waterbodies.
- Consider that decreased performance can occur due to ultra-violet light and time after mixing when applying anionic PAM.
- In concentration channels, the effectiveness of anionic PAM for stabilization decreases.
- If seed is applied with anionic PAM, mulch should be used to protect seed.
- Never add water to PAM, PAM must be slowly added to water.
- NOT ALL POLYMERS ARE PAM.

Installation

The manufacturer's guidelines for application should be followed.

- Only use the anionic form of PAM. Cationic PAM is toxic and should NOT be used.
- PAM and PAM mixtures have to be environmentally harmless, harmless to fish, wildlife, and plants.
- The pure form of anionic PAM should have less than or equal to 0.05 percent acrylamide monomer by weight, as established by FDA and EPA.
- In order to maintain less than or equal to 0.05 percent of acrylamide monomer, the maximum application rate of PAM, in pure form, should not exceed 200 pounds/acre/year. Do not over apply.
- Users of anionic PAM should obtain and follow all MSDS requirements and manufacturer's recommendations. The following criteria are generally included on the MSDS:
  - Ultra high molecular weight of 6 to 24 mg/mole (preferably 12-15 mg/mole)
  - Non-combustible
  - Does not change soil pH
  - Expiration date included
- Additives such as fertilizers, solubility promoters or inhibitors to PAM should be non-toxic.
- To prevent exceeding the acrylamide monomer limit in the event of a spill, the pure form of anionic PAM should not exceed 200 pounds/batch at 0.05 percent acrylamide monomer (AMD) or 400 pounds/batch at 0.025 percent AMD.

Inspection and Maintenance

- PAMs have been estimated to degrade approximately 10 percent per year. The effects are accelerated in highly exposed areas.
- If PAM treated soil is left undisturbed, reapplication may be necessary after 6-8 weeks.
- Further anionic PAM applications may be required for disturbed areas including highly silty and clayey soils, steep slopes, long grades, and high traffic or precipitation areas.
- All equipment should be maintained to provide the application rates recommended by the manufacturer.
- Rinse all equipment used to mix and apply anionic PAM thoroughly with water.

Liquid PAM

Solid/Block PAM

Preventive Measures and Troubleshooting Guide

Field Condition	Common Solutions
Slope was improperly dressed before application.	Roughen slope and fill damaged areas.
Coverage is inadequate.	Follow recommended application rates. Reapply to thin areas.
Sprayed areas degrade or become ineffective.	Follow recommended application rates. Consider other or additional BMPs. Reapply as necessary.
Sprayed slope has spot failures.	Repair slopes, add jute netting and re-spray damaged areas.
Portions of the sprayed area have been disturbed.	Keep workers and equipment off sprayed areas. Repair and re-spray areas that have been damaged.
PAM is washed off slope.	Allow at least 24 hours for the materials to dry before a rain event. Follow manufacturer's recommendations. Reapply as necessary.
Excessive water flows across stabilized surface.	Use other BMPs to limit flow on stabilized area. Use other BMPs to reduce slope lengths. Do not use to stabilize slopes with swift moving concentrated flows.